

Land surface Verification Toolkit (LVT)

User's Guide

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Revision 1.0

History:

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1.0	Initial version for LIS 6.0	August, 2009



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1 Introduction

This is the User's Guide for Land surface Verification Toolkit (LVT). This document describes how to download and install LVT codes and instructions on building an executable.

This document consists of several sections, described as follows:

- 1 Introduction:** the section you are currently reading
- 2 Background:** general information about the LVT
- 3 Preliminaries:** general information, steps, instructions, and definitions used throughout the rest of this document
- 4 Obtaining the Source Code:** the steps needed to download the source code
- 5 Building the Executable:** the steps needed to build the LVT executable

1.1 What's New

1.1.1 Version 1.0

1. This is the initial version developed for evaluating output from LIS version 6.0 or higher.

2 Background

Verification and evaluation are essential processes in the development and application of simulation models. The Land surface Verification Toolkit (LVT) is an integrated framework designed specifically for evaluating land surface model (LSM) outputs. The system was originally designed as a post processor to the NASA Land Information System (LIS), which is an integrated framework to conduct multi-model land surface model simulations and data assimilation integrations. LVT also includes the capabilities to convert any land surface-specific dataset to a “LIS output format/style”, thus enabling cross-comparisons of a broad set of land surface datasets (in-situ, remotely sensed, and reanalysis products).

2.1 LVT

LVT provides a formal system for LSM output evaluation and verification. The capabilities of LVT also provides a tool to systematically evaluate and benchmark LSM performance and the impact of computational enhancements such as data assimilation. LVT includes a range of both deterministic and probabilistic verification measures, with similarity-based and object-based methods in development.

LVT is designed as an object oriented framework, with a number of points of flexibility known as “plugins”. Specific implementations are added to the framework through the plugin-interfaces. LVT uses the plugin-based architecture to support the processing of different types of observational data sets, ranging from in-situ, satellite and remotely sensed and reanalysis products.

In addition to providing methods for model output verification, LVT also provides capabilities to analyze the outputs from LIS data assimilation (LIS-DA) and the LIS optimization and uncertainty estimation (LIS-OPTUE) subsystems.

2.2 Summary of key features

The key capabilities of LVT can be summarized as follows:

- Capability to convert a given dataset to “LIS-style format”
- A text-based, configurable input interface
- Supports a broad range of in-situ, remotely-sensed and reanalysis data products. For e.g.:
 - Surface fluxes - Ameriflux, ARM, CEOP, AMMA
 - Soil moisture - SCAN, SMOSREX, AMSR-E retrievals
 - Snow - COOP, GSOD, SNODAS, SNOADEP, CMC, FMI, GlobSnow, SNOTEL
 - LST - ISCCP

– Radiation - SURFRAD

- A number of deterministic and probabilistic verification measures. E.g. RMSE, Bias, Correlations, POD, FAR, etc.
- Supports the computation of land surface model diagnostics and closure checks. E.g.: Energy, water balance checks, seasonal and average diurnal cycles
- Options of time series extraction of individual grid points and area averages
- Options of temporal averaging. E.g. : Comparisons at hourly, daily, monthly scales
- Options for data masking. E.g. Apply an external mask to the comparisons, apply thresholds on the comparisons
- Supports the analysis of outputs from LIS-OPTUE and LIS-DA subsystems. For e.g: Analysis of normalized innovations from LIS-DA

3 Preliminaries

This section provides some preliminary information to make reading this guide easier.

Commands are written like this:

```
% cd /path/to/LVT  
% ls  
“... compiler flags, the run gmake.”
```

File names are written like this:

```
/path/to/LVT/src
```

You need to create a working directory on your system to install LVT. Let's call this directory */path/to/LVT/*. Throughout the rest of this document, this directory shall be referred to as *\$WORKING*. You should create a directory to run LVT in. This directory can be created anywhere on your system, but, in this document, we shall refer to this running directory as *\$WORKING/run*.

4 Obtaining the Source Code

This section describes how to obtain the source code needed to build the LVT executable.

The source code is maintained in a Subversion repository; thus, you need the Subversion client (svn) to obtain this code. If you need any help regarding Subversion, please go to <http://subversion.tigris.org/>.

4.1 Downloading the Source Code

To obtain the source code needed for LVT, you must first obtain access to the LIS source code respository. To obtain access you must contact the LIS team. Once you have access to the repository, you will be given the correct Subversion command to run to checkout the source code.

1. Go to the working directory

```
% cd $WORKING
```

2. Check out the LIS source code into a directory called *src* under the \$WORKING directory.

```
% svn checkout https://flood.gsfc.nasa.gov/svn/tools/lvt/ src
```

5 Building the Executable

This section describes how to build the source code and create LVT executable

5.0.1 Development Tools

This code has been compiled and run on Linux PC (Intel/AMD based) systems, IBM AIX systems, and SGI Altix systems. These instructions expect that you are using such a system. In particular you need

- Linux
 - Absoft's Pro Fortran Software Development Kit, version 10.0
or
 - Lahey/Fujitsu's Fortran 95 Compiler, release L6.00c
 - GNU's C and C++ compilers, gcc and g++, version 3.3.3
 - GNU's make, gmake, version 3.77
- IBM
 - XL Fortran version 10.1.0.6
 - GNU's make, gmake, version 3.77
- SGI Altix
 - Intel Fortran Compiler version 11.1.038
 - GNU's make, gmake, version 3.77

5.0.2 Required Software Libraries

In order to build the LVT executable, the following libraries must be installed on your system:

- Earth System Modeling Framework (ESMF) version 3.1.0rp2 (<http://www.esmf.ucar.edu/>)
Please read the ESMF User's Guide for details on compiling ESMF with MPI support and without MPI support ("mpuni"). Note that ESMF must be compiled with MPI support for using LIS-WRF system in a multiprocessor environment.

5.0.3 Optional Software Libraries

The following libraries are not required to compile LVT. They are used to extend the functionality of LVT.

- Message Passing Interface (MPI) – If you wish to run the MPI-based running mode
 - vendor supplied, or

- MPICH version 1.2.7p1 (<http://www-unix.mcs.anl.gov/mpi/mpich1/>)
- If you choose to have NETCDF support, please download the netcdf source (<http://www.unidata.ucar.edu/software/netcdf/>) and compile the source to generate the NETCDF library.

To install these libraries, follow the instructions provided at the various URL listed above.

5.0.4 Build Instructions

1. Perform the steps described in Section 4 to obtain the source code.
2. Goto the `$WORKING/src/arch` directory. A number of files named `configure.lvt.*` exist in this directory. Each file contains the configurable options that are specific for each architecture and compiler. For example, the file `configure.lvt.aix` contains the set of configurable options for an IBM AIX platform. Depending on your choice of platform, edit this file or create a new file for your platform with the set of options. The following is a list of variables that need to be specified in the `configure.lvt` file.

Variable	Description
<code>FC</code>	Fortran 90 compiler
<code>FC77</code>	Fortran 77 compiler
<code>LD</code>	Fortran linker
<code>CC</code>	C compiler
<code>AR</code>	program to create a library archive
<code>INC_NETCDF</code>	path to NETCDF header files
<code>LIB_NETCDF</code>	path to NETCDF library files
<code>INC_HDF</code>	path to HDF header files
<code>LIB_HDF</code>	path to HDF library files
<code>INC_HDFEOS</code>	path to HDFEOS header files
<code>LIB_HDFOEOS</code>	path to HDFEOS library files
<code>INC_CRTM</code>	path to CRTM header files
<code>LIB_CRTM</code>	path to CRTM library files
<code>LIB_MPI</code>	path to mpi libraries
<code>INC_MPI</code>	path to mpi header files
<code>LIB_ESMF</code>	path to esmf libraries
<code>MOD_ESMF</code>	path to esmf modules
<code>CFLAGS</code>	flags for C compiler
<code>FFLAGS</code>	flags for Fortran 90 compiler
<code>FFLAGS77</code>	flags for Fortran 77 compiler
<code>LDFLAGS</code>	flags for linker

If the user chooses to compile and run on a single processor with no MPI, the options in the `configure.lvt` file should be specified accordingly. Specifying the compiler preprocessor flag `-DSPMD` enables the compiling of the code with MPI support. Removing this flag produces a serial version of LVT.

- Set the LIS_ARCH environment variable based on the system you are using. The following commands are written using Bash shell syntax.

- For an AIX system
% export LIS_ARCH=AIX
- For a Linux system with the Intel Fortran compiler
% export LIS_ARCH=linux_ifc
- For a Linux system with the Intel Fortran and gcc C compiler
% export LIS_ARCH=linux_gcc
- For a Linux system with the Absoft Fortran compiler
% export LIS_ARCH=linux_absoft
- For a Linux system with the Lahey Fortran compiler
% export LIS_ARCH=linux_lf95

It is suggested that you place this command in your *.profile* (or equivalent) startup file.

- Compile the new GRIB library, *libw3.a*. Go into *\$WORKING/lib/w3lib* and run **gmake**.
- Compile the new GRIB library, *griblib.a*. Go into *\$WORKING/lib/grib* and run **gmake**.
- Compile the new GRIB library, *read_grib*. Go into *\$WORKING/lib/read_grib* and run **gmake**.
- All the included libraries are generated. Copy the appropriate *configure.lvt.** file to *\$WORKING/src/make/configure.lvt* and edit this *configure.lvt* file to make sure the file paths are specified correctly.
- Compile the dependency generator, *makdep*. Change directory into *\$WORKING/src/make/MAKDEP*. Run **gmake**.
- Compile the LVT source code.
 - Change directory into *\$WORKING/src/make*.
% cd \$WORKING/src/make
 - Edit the *misc.h* file to specify if NETCDF support should be included.
If **define USE_NETCDF** is set, NETCDF support will be included.
To disable NETCDF support, edit the *misc.h* file to specify **UNDEF USE_NETCDF**.
 - Edit the *misc.h* file to specify if HDF4 support should be included.
If **define USE_HDF4** is set, HDF4 support will be included.
To disable HDF4 support, edit the *misc.h* file to specify **UNDEF USE_HDF4**.

- (d) Edit the *misc.h* file to specify if HDF4 support should be included.
If `define USE_HDF5` is set, HDF5 support will be included.
To disable HDF5 support, edit the *misc.h* file to specify `UNDEF USE_HDF5`.
- (e) Run the make command.
`% gmake`
- (f) Finally, copy the *LVT* executable into your running directory, `$WORKING/run`.

See Appendix H to see a *configure.lvt* file.

5.1 Generating documentation

LVT code uses the ProTex documenting system [1]. The documentation in L^AT_EX format can be produced by using the `doc.csh` in the `$WORKING/src/utils` directory. This command produces documentation, generating a number of L^AT_EX files. These files can be easily converted to pdf or html formats using utilites such as `pdflatex` or `latex2html`.

6 Running the Executable

This section describes how to run the LVT executable.

The single-process version of LVT is executed by the following command issued in the `$WORKING/run/` directory.

```
% ./LVT <configfile>
```

where `<configfile>` represents the file containing the run time configuration options for LVT.

The parallel version of LVT must be run through an `mpirun` script or similar mechanism. Assuming that MPI is installed correctly, the LVT simulation is carried out by the following command issued from in the `$WORKING/run/` directory.

```
% mpirun -np N ./LVT <configfile>
```

The `-np N` flag indicates the number of processes to use in the run, where you replace `N` with the number of processes to use. On a multiprocessor machine, the parallel processing capabilities of LVT can be exploited using this flag.

To customize your run, you must specify a LVT runtime configuration file. See Section 7 for more information.

7 LVT config File

This section describes the options in the *lvt.config* file.

7.1 Overall driver options

LIS Running mode: specifies the running mode to be used Acceptable values are:

Value	Description
0	observation processing (to convert to a "LIS format")
1	standard analysis mode
2	data assimilation diagnostics analysis
3	data assimilation observation analysis
6	parameter estimation/uncertainty output analysis
7	RTM (radiative transfer model) output analysis

LIS Running mode: 1

LIS Domain type: specifies the "LIS domain" used in the LIS simulation Acceptable values are:

Value	Description
1	Lat/Lon projection with SW to NE data ordering
2	Mercator projection with SW to NE data ordering
3	Lambert conformal projection with SW to NE data ordering
4	Gaussian domain
5	Polar stereographic projection with SW to NE data ordering
6	AFWA lat/lon 0.5 degree/0.25 degree domain with no subgrid tiling
7	UTM domain
8	HRAP domain
10	Catchment based domain
11	GSPW domain

LIS Domain type: 1

LIS nest index: specifies the nest index of the LIS output being compared using LVT

LIS nest index: 1

Land surface model: specifies the land surface model used in the LIS simulation Acceptable values are:

Value	Description
0	template lsm
1	Noah 2.7.1
2	CLM 2.0
3	VIC
4	mosaic
5	hyssib
6	sib2
7	catchment
8	sacramento
9	snow17
10	sacramento+snow17
11	sib3
12	mlbc
13	csu
14	place
21	noah 3.1

Land surface model: 1

LIS Output format: specifies the format of the LIS output data. Acceptable values are:

Value	Description
1	LIS output in binary format
2	LIS output in Grib format
3	LIS output in NETCDF format

LIS Output format: 1

LIS Output format: specifies the style of the model output names and their directory organization Acceptable values are:

Value	Description
1	5 levels of hierarchy
2	3 levels of hierarchy
3	2 levels of hierarchy
4	WMO convention for weather codes

LIS Output naming style: 1

Map projection of parameter data: specifies the map projection of the parameter datasets. Note that the grid description options for the parameters will be different for different map projections

Acceptable values are:

Value	Description
0	Equidistant cylindrical (lat/lon)
4	Gaussian
5	Polar Stereographic
6	UTM projection

Map projection of parameter data: 0

Number of observation sources: specifies the number of observational data sources to be used in comparisions

Number of observation sources: 1

Observation source: specifies the observational data to be used for comparing LIS model output

Acceptable values are:

Value	Description
0	template
1	output from another LIS run
2	CEOP station observations
3	ISCCCP skin temperature observations
4	SCAN soil moisture station observations
5	Oklahoma mesonet station observations
6	COOP snow depth observations
7	SURFRAD radiation observations
8	PBMR soil moisture observations at Walnut Gulch
9	SNOTEL snow water equivalent observations
10	GSOD snow depth observations
11	Tb brightness temperature observations at the LSWG sites
12	Finnish Meteorological Institute (FMI) snow course data
13	Canadian Meteorological Center's (CMC) snow depth analysis
14	NOHRSC's SNOW Data Assimilation (SNODAS) product.

Observation source: 6 #coop

7.2 Runtime options

Experiment code: specifies the “experiment code number” used in the LIS run. It is used in constructing the name of the output directory for the run. Acceptable values are any name using up to 3 characters.

Experiment code: 111

The start time of the evaluation period is specified in the following format:

Variable	Value	Description
Starting year:	integer 2001 – present	specifying starting year
Starting month:	integer 1 – 12	specifying starting month
Starting day:	integer 1 – 31	specifying starting day
Starting hour:	integer 0 – 23	specifying starting hour
Starting minute:	integer 0 – 59	specifying starting minute
Starting second:	integer 0 – 59	specifying starting second

Starting year: 2007
 Starting month: 11

Starting day:	1
Starting hour:	0
Starting minute:	0
Starting second:	0

The end time of the evaluation period is specified in the following format:

Variable	Value	Description
Ending year:	integer 2001 – present	specifying ending year
Ending month:	integer 1 – 12	specifying ending month
Ending day:	integer 1 – 31	specifying ending day
Ending hour:	integer 0 – 23	specifying ending hour
Ending minute:	integer 0 – 59	specifying ending minute
Ending second:	integer 0 – 59	specifying ending second

Ending year:	2008
Ending month:	5
Ending day:	31
Ending hour:	0
Ending minute:	0
Ending second:	0

LVT Output format: specifies the format of the LVT output. Acceptable values are:

Value	Description
1	Write output in binary format
2	Write output in Grib format (not supported yet)
3	Write output in NETCDF format

See Appendix A for more details about the structure of the LVT output files.

LVT Output format: 3

LIS Output timestep: specifies the frequency of model outputs used in the LIS simulation (in seconds)

LIS Output timestep:	10800
----------------------	-------

Undefined value: specifies the undefined value. The default is set to -9999.

Undefined value: -9999

LVT diagnostic file: specifies the name of run time diagnostic file. Acceptable values are any 40 character string.

LVT diagnostic file: lvtlog

LIS Output methodology: specifies the output methodology used in the LIS simulation. The LIS output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

Value	Description
1	LIS output in a 1-D tile domain
2	LIS output in a 2-D grid domain
3	LIS output in a 1-D grid domain

LIS Output methodology: 2

LVT Output methodology: specifies the output methodology used in the LVT. The LVT output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

Value	Description
1	LVT output in a 1-D tile domain
2	LVT output in a 2-D grid domain
3	LVT output in a 1-D grid domain

LVT Output methodology: 2

LIS Output directory: specifies the name of the top-level LIS output directory. Acceptable values are any 40 character string. For simplicity, throughout the rest of this document, this top-level output directory shall be referred to by its default name, \$WORKING/LIS/OUTPUT.

```
LIS Output directory:          ./CTRL/OUTPUT
```

Number of ensembles per tile: specifies the number of ensembles of tiles used in the LIS simulation. The value should be greater than or equal to 1.

```
Number of ensembles per tile:      1
```

This section specifies the 2-d layout of the processors in a parallel processing environment. The user can specify the number of processors along the east-west dimension and north-south dimension using **Number of processors along x:** and **Number of processors along y:**, respectively. Note that the layout of processors should match the total number of processors used. For example, if 8 processors are used, the layout can be specified as 1x8, 2x4, 4x2, or 8x1.

```
Number of processors along x:    2  
Number of processors along y:   2
```

7.3 Domain specification

This section of the config file specifies the running domain (domain over which the simulation is carried out). The specification of the running domain section depends on the type of LIS domain and projection used. Section 7.1 lists the projections that LIS supports.

7.3.1 Cylindrical lat/lon

This section describes how to specify a cylindrical latitude/longitude projection. See Appendix B for more details about setting these values.

```
run domain lower left lat:        30.125  
run domain lower left lon:       -124.875  
run domain upper right lat:      50.125  
run domain upper right lon:     -69.875  
run domain resolution (dx):     0.25  
run domain resolution (dy):     0.25
```

```
#Definition of Parameter Domain
```

7.3.2 Cylindrical lat/lon

This section describes how to specify a cylindrical latitude/longitude projection. See Appendix B for more details about setting these values.

```
param domain lower left lat:          -59.875
param domain lower left lon:          -179.875
param domain upper right lat:         89.875
param domain upper right lon:         179.875
param domain resolution (dx):        0.25
param domain resolution (dy):        0.25
```

Number of veg types: specifies the number of vegetation types used in the landcover data, used in the LIS simulation Acceptable values are:

Value	Description
13	UMD-based landcover types
16	IGBP-based landcover types
30	USGS-based landcover types

Number of veg types: 24

The following options are used for subgrid tiling based on vegetation

Maximum number of tiles per grid: defines the maximum tiles per grid (this can be as many as the total number of vegetation types), used in the LIS simulation

Maximum number of tiles per grid: 1

Cutoff percentage: defines the smallest percentage of a cell for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

Cutoff percentage: 0.05

Landcover data source: specifies the usage of landcover data in the LIS run.
Acceptable values are:

Value	Description
1	UMD landcover
2	USGS landcover data
3	GFS landcover data
4	IGBP landcover data

landcover data source:

2

landmask file: specifies the location of land/water mask file.

landcover file: specifies the location of the vegetation classification file

landcover file format: specifies if the vegetation file is tiled or not (0-not tiled, 1- tiled)

landmask file:

./input/AFWA-25KM/mask_25KM.1gd4r

landcover file:

./input/UMD-25KM/usgs_veg_25km.1gd4r

landcover file format:

0

This section should also specify the domain specifications of the landcover data. If the map projection of parameter data is specified to be lat/lon, the following configuration should be used for specifying landcover data See Appendix B for more details about setting these values.

```
landcover lower left lat:      -59.875
landcover lower left lon:      -179.875
landcover upper right lat:     89.875
landcover upper right lon:    179.875
landcover resolution (dx):    0.25
landcover resolution (dy):    0.25
```

LIS output attributes file: specifies the output attributes file. This file can be specified by using the model output attributes used to for customizing the LIS model output. An extra column needs to be added in this file to specify which variables among the LIS output are to be included in the evaluation/verification.

```
LIS output attributes file:    './MODEL_OUTPUT_LIST_LVT.TBL'
```

LIS soil moisture layer thickness: specifies the thickness values of the soil moisture layers

```
LIS soil moisture layer thickness:    100 300 600 1000
```

LIS soil temperature layer thickness: specifies the thickness values of the soil temperature layers

```
LIS soil temperature layer thickness: 100 300 600 1000
```

7.4 Analysis options specification

This section of the config file specifies the type of analysis to be conducted during the verification/evaluation. Note that some options are only available in certain running modes.

Apply external mask: Specifies whether to apply an external mask in limiting the analysis to a selected set of data points

Acceptable values are:

Value	Description
0	Do not apply external mask
1	Apply external, temporally varying mask
2	Apply fixed mask

```
Apply external mask:          0
```

External mask directory: Specifies the name of the data mask file/directory. If the mask varies temporally, then this option specifies the top-level directory containing data mask. Note that the mask files are expected to be in binary, sequential access format.

External mask directory: none

Compute Mean (Total): Specifies if temporal mean values of LIS output (for the entire evaluation period) are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Mean (Total):

Compute Mean (Time Series): Specifies if temporal mean values of LIS output (based on the frequency of statistics output) are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Mean (Time Series):

Compute Std: Specifies if standard deviation values of LIS output (based on the specified time period) are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Std:

Compute RMSE (Total): Specifies if RMSE values for the entire evaluation time period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute RMSE (Total): 1

Compute Bias (Total): Specifies if Bias values for the entire evaluation time period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Bias (Total): 1

Compute RMSE (Time Series): Specifies if a time series of RMSE values during the evaluation period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute RMSE (Time Series): 1

Compute Bias (Time Series): Specifies if a time series of Bias values during the evaluation period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Bias (Time Series): 1

Compute Anomaly Correlations: Specifies if anomaly time series correlation coefficient values (for the entire evaluation period) are to be computed. Note that if masking is turned on, the code will use only "unmasked" data points for computations.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Anomaly Correlations: 0

Compute Raw Correlations: Specifies if raw time series correlation coefficient values (for the entire evaluation period) are to be computed. Note that if masking is turned on, the code will use only "unmasked" data points for computations.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Raw Correlations: 0

Compute POD (Total): Specifies if probability of detection values for the entire evaluation time period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute POD (Total): 1

Compute POD (Time Series): Specifies if a time series of Probability of detection (POD) values (based on the frequency of statistics output) during the evaluation period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute POD (Time Series): 1

Compute FAR (Total): Specifies if false alarm ratio values for the entire evaluation time period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute FAR (Total):

1

Compute FAR (Time Series): Specifies if a time series of false alarm ratio (FAR) values (based on the frequency of statistics output) during the evaluation period are to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute FAR (Time Series):

1

Compute Peak Detection: Specifies if the time of occurrence of peak values of variables are to be computed. The code will output the peak occurrence times of the model values and the observations

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

Compute Peak Detection:

1

Observation count threshold: Specifies the number of observations to be used as the minimum threshold for computing statistics. Grid points with observation count less than this value will be ignored.

Acceptable values are 0 or higher

Observation count threshold:

0

Temporal averaging interval: Specifies (in seconds) the temporal averaging interval of the LIS output and observation data.

Temporal averaging interval: 86400

Stats output directory: Specifies the top-level directory where the output from the analysis is to be written.

Stats output directory: ./STATS

Stats output interval: Specifies the frequency (in seconds) of the analysis output

Stats output interval: 86400

Extract time series: Specifies if an ASCII time series file of model output and observations are to be written, for specified locations in the domain.

Extract time series: 1

Time series location file: Specifies the name of the file which lists the locations in the domain where the time series data are to be derived. The format of the time series location file is as follows:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile)
1
#Location name (location 1)
WEST_US
#lat/lon values
40 -130 50 -110
#Location name (location 2)
HIGH_PLAINS_US
#lat/lon values
43 -110 49 -100
```

```
Time series location file:          ./ts_locations.txt
```

7.5 Observation sources

This section of the config file specifies the details of the observational sources.

7.5.1 LIS LSM output as the observation

LISlsmObs model name: name of the model used in the simulation. Acceptable values are:

Value	Description
NOAH	Noah land surface model
CLSM	Catchment land surface model

LISlsmObs number of variables in output: specifies the number of simulated variables in the output

LISlsmObs domain type: specifies the domain type used in generating the output

LISlsmObs nest index: specifies the nest index of the domain

LISlsmObs experiment code: specifies the experiment code number used in the simulation

The domain should be specified, based on the domain type. **LISlsmObs model output attributes file:** specifies the model output attribute file used for generating the output

```
LISlsmObs model name:      CLSM
LISlsmObs number of variables in output:   23
LISlsmObs domain type:           1
LISlsmObs nest index:          1
LISlsmObs experiment code:    111
LISlsmObs output directory:   ./CLSM/OUTPUT
LISlsmObs domain lower left lat: 30.5
LISlsmObs domain lower left lon: -124.5
LISlsmObs domain upper right lat: 50.5
LISlsmObs domain upper right lon: -75.5
LISlsmObs domain resolution (dx): 1.0
```

```
LISlsmObs domain resolution (dy):           1.0
LISlsmObs model output attributes file:   './CLSM_OUTPUT_LIST.TBL'
```

7.5.2 CEOP station observations

CEOP undefined value: specifies the undefined value used in CEOP data
CEOP metadata file: specifies the file that lists the metadata for the CEOP stations.
CEOP read surface meteorology data: specifies whether to read the surface meteorology data (.true. or .false.)
CEOP read flux data: specifies whether to read the surface fluxes data (.true. or .false.)
CEOP read soil moisture and temperature data: specifies whether to read the soil moisture and temperature data (.true. or .false.)
CEOP soil moisture layer weights: specifies the vertical interpolation weights for soil moisture
CEOP soil temperature layer weights: specifies the vertical interpolation weights for soil temperature
CEOP surface meteorology data file: specifies the surface meteorology data file
CEOP flux data file: specifies the flux data file
CEOP soil temperature and moisture data file: specifies the soil temperature and moisture data file.

CEOP undefined value:	-999.99
CEOP metadata file:	./bon.mdata
CEOP read surface meteorology data:	.true.
CEOP read flux data:	.true.
CEOP read soil moisture and temperature data:	.true.
CEOP soil moisture layer weights:	3 2 6 10 22 42
CEOP soil temperature layer weights:	3 2 6 10 22 42
CEOP surface meteorology data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231.sfc
CEOP flux data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231.flx
CEOP soil temperature and moisture data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231.sfc

7.5.3 ISCCP land surface temperature observations

ISCCP Tskin data directory: specifies the location of the ISCCP land surface temperature data

```
ISCCP Tskin data directory:      './ISCCP'
```

7.5.4 SCAN soil moisture observations

SCAN observation directory: specifies the location of the SCAN soil moisture observation data

SCAN coord file: specifies the file that lists the location of the SCAN stations. The format of the metadata file is as follows: SCAN station id, station lat, station lon

```
2062 59.68 -151.37
2081 64.69 -148.91
2063 59.68 -151.38
2080 63.35 -142.98
2095 63.95 -145.08
....
```

SCAN metadata file: specifies the file that lists the metadata for the SCAN stations. The format of the metadata file is as follows:

```
#nstns udef  syr  smo  sda  smn  eyr  eda  emo  ehr  emn  ts
179 -99.999 2007 11 01 01 00 2008 06 01 00 00 3600
```

SCAN soil moisture layer weights: specifies the vertical interpolation weights for soil moisture
SCAN soil temperature layer weights: specifies the vertical interpolation weights for soil temperature

SCAN observation directory:	./SCAN/
SCAN coord file:	./SCAN_coord.txt
SCAN metadata file:	./SCAN_mdata

```
SCAN soil moisture layer weights:    0.075 0.075 0.205 0.460 0.185
SCAN soil temperature layer weights: 0.075 0.075 0.205 0.460 0.185
```

7.5.5 COOP snow depth observations

COOP observation directory: specifies the location of the COOP snow depth observation data

COOP coord file: specifies the file that lists the location of the COOP stations. The format of the station list is as follows:

010008	ABBEVILLE	31.570	-84.752
010116	ALABASTER SHELBY CO AP	33.178	-85.218
010140	ALBERTA	32.232	-86.589
.....			
.....			

COOP metadata file: specifies the file that lists the metadata for the COOP stations. The format of the metadata file is as follows:

```
#nstns udef    syr    smo    sda    smn    eyr    eda    emo    ehr    emn    ts
10395 -9999.0 2007 11 01 01 00 2008 06 01 00 00 3600
#nstates
47
#state names
AL
AR
AZ
CA
CO
CT
FL
GA
IA
ID
IL
IN
KS
KY
LA
MA
MD
```

ME
MI
MN
MO
MS
MT
NC
ND
NE
NH
NJ
NM
NV
NY
OH
OK
OR
PA
RI
SC
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY

COOP observation directory: ./COOP
COOP coord file: ./COOP/COOP_stnlist.dat
COOP metadata file: ./COOP/COOP_mdata

7.5.6 SURFRAD radiation observations

SURFRAD observation directory: specifies the location of the SURFRAD radiation data

SURFRAD observation directory: ../SURFRAD

7.5.7 Walnut Gulch PBMR soil moisture observations

WG PBMR observation directory: specifies the location of the Walnut Gulch PBMR soil moisture observation data

WG PBMR site index: specifies the station being used

WG PBMR observation directory: ./WG PBMR
WG PBMR coord file: 1

7.5.8 SNOTEL SWE observations

SNOTEL observation directory: specifies the location of the SNOTEL SWE observation data

SNOTEL coord file: specifies the file that lists the location of the SNOTEL stations. The format of the station list is as follows:

AZ	BAKER BUTTE	11R06S	308	34.450	-111.400
AZ	BAKER BUTTE SMT	11R07S	1140	34.450	-111.367
AZ	BALDY	09S01S	310	33.967	-109.500
AZ	BEAVER HEAD	09S06S	902	33.683	-109.200

.....

.....

SNOTEL metadata file: specifies the file that lists the metadata for the SNOTEL stations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time data, timestep
712 -9999.0 2007 01 01 01 00 2008 12 31 00 00 86400
```

SNOTEL observation directory:	./SNOTEL
SNOTEL coord file:	./SNOTEL/SNOTEL_CONUS_list.txt
SNOTEL metadata file:	./SNOTEL/SNOTEL_mdata

7.5.9 GSOD snow depth observations

GSOD observation directory: specifies the location of the GSOD snow depth observation data

GSOD coord file: specifies the file that lists the location of the GSOD stations. The format of the station list is as follows:

000000 99999 NYGGBUKTA GREENLAND- STA	GL GL	+73483 +021567 +00030
000010 99999 JAN HAYEN	NO NO	+70983 -007700 +00229
000020 99999 ISFJORD RADIO SPITZBERGEN	NO NO	+78067 +013633 +00079
000030 99999 BJORNOYA BARENTS SEA	NO NO	+74467 +019283 +00290
000040 99999 VAROO	NO NO	+70367 +031100 +00119
000050 99999 INGOY	NO NO	+71067 +024150 +00040
.....		
.....		

GSOD metadata file: specifies the file that lists the metadata for the GSOD stations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time data, timestep
30727 -9999.0 2007 11 01 01 00 2008 06 01 00 00 86400
```

GSOD observation directory:	./GSOD
GSOD coord file:	./GSOD/GSOD_CONUS_list.txt
GSOD metadata file:	./GSOD/GSOD_mdata

7.5.10 LSWG Tb observations

LSWG Tb observation filename: specifies the name of the LSWG filename containing Brightness Temperature (Tb) observations

LSWG Tb satellite name: specifies the name of satellite – same as what's used in CRTM

LSWG Tb data format: 0 for AMSR-E, 1-for AMSU **LSWG Tb metadata file:** specifies the file that lists the metadata for LSWG Tb observations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time, timestep (mins)
1 -1 2006 07 01 10 00 2007 06 30 17 00 3600
#LIS channel data index in file
1   1
2   2
3   3
4   4
5   5
6   6
7   7
8   8
9   9
10 10
11 11
12 12
13 13
14 14
15 15
```

LSWG Tb include cloud masking: specifies if data is to be ignored in the presence of clouds (0-do not ignore, 1-ignore) **LSWG Tb cloud mask file:** specifies the name of the cloud mask file **LSWG Tb cloud mask column:** ?? **LSWG Tb cloud mask threshold(%):** specifies the threshold below which clouds can be ignored (used only if cloud masking is enabled).

```
LSWG Tb observation filename:      './_LSWG/C3VP.txt'
LSWG Tb satellite name:           'N18_'
LSWG Tb data format:              1
LSWG Tb metadata file:            ./C3VP_mdata
LSWG Tb include cloud masking:    1
LSWG Tb cloud mask file:          ./cloud_mask.txt
LSWG Tb cloud mask column:        ???
LSWG Tb cloud mask threshold(%): 75
```

7.5.11 FMI SWE observations

FMI observation directory: specifies the location of the FMI snow course data

FMISWE observation directory: . /FMI_SWE

7.5.12 CMC's daily snow depth observations

CMC SNWD observation directory: specifies the location of the CMC snow depth observation data

CMC SNWD metadata file: specifies the file that lists the metadata for the CMC snow depth data. The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep  
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

CMC SNWD observation directory:

. /CMC_data

CMC SNWD metadata file:

. /CMC_data/CMC_SNWD_mdata

7.5.13 SNODAS snow analysis data

SNODAS observation directory: specifies the location of the SNODAS data

SNODAS metadata file: specifies the file that lists the metadata for the SNODAS.

The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep  
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

SNODAS observation directory: ./SNODAS
SNODAS metadata file: ./SNODAS/SNODAS_mdatal

7.5.14 NASA AMSR-E soil moisture retrievals

NASA AMSR-E soil moisture observation directory: specifies the location of the standard (NASA) AMSR-E soil moisture retrievals

NASA AMSRE soil moisture observation directory: ./NASA_AMSRE

7.5.15 NESDIS AMSR-E soil moisture retrievals

NESDIS AMSR-E soil moisture observation directory: specifies the location of the NESDIS AMSR-E soil moisture retrievals

NESDIS AMSRE soil moisture observation directory: ./NESDIS_AMSRE

7.5.16 VU AMSR-E soil moisture retrievals

VU AMSR-E soil moisture observation directory: specifies the location of the University of Amsterdam (Vrije Universiteit - VU) AMSR-E soil moisture retrievals

VU AMSRE soil moisture observation directory: ./VU_AMSRE

7.5.17 AMMA station observations

AMMA observation directory: specifies the location of the AMMA in-situ observations.
AMMA static txt file list: specifies the file with the station file names in text format (.txt)

A sample static txt file list is shown below:

```
12  
201006140332132535.csv  
201006140337342536.csv  
201006140347082537.csv  
201006140348592538.csv  
201006140351382539.csv  
201006140358582540.csv  
201006140400532541.csv  
201006140402202542.csv  
201006140640302543.csv  
201006140641442544.csv  
201006140642422545.csv  
201006140643372546.csv
```

AMMA static netcdf file list: specifies the file with the station file names in netcdf format

A sample static txt file list is shown below:

```
10  
ceh-aws_agoufou_20050414.nc  
ceh-aws_bamba_20050426.nc  
ceh-aws_banizoumbou_20051115.nc  
ceh-aws_belifoungou_20051111.nc  
ceh-aws_bira_20051113.nc  
ceh-aws_hedgerit_20050415.nc  
ceh-aws_kelema_20050416.nc  
ceh-aws_nalohou_20051111.nc  
ceh-aws_pobe_20050220.nc  
ceh-aws_wankama_20051117.nc
```

AMMA soil moisture layer weights: normalized weights to be applied for root zone computations of soil moisture **AMMA soil temperature layer weights:** normalized weights to be applied for root zone computations of soil temperature

```

AMMA observation directory:          ./AMMA/
AMMA static txt file list:          amma_static_txtfiles.txt
AMMA static netcdf file list:       amma_static_ncfiles.txt
AMMA soil moisture layer weights:   0.1875 0.1875 0.625 0.0 0.0
AMMA soil temperature layer weights: 0.1875 0.1875 0.625 0.0 0.0

```

7.5.18 Ameriflux station observations

Ameriflux observation directory: specifies the location of the Ameriflux datasets. **Ameriflux station list file:** specifies the file that lists the location of the Ameriflux stations. The format of the station list is as follows:

```

#nstns
76
#stnname; location name; lat; lon; SWC1 depth; SWC2 depth; TS1 depth; TS2 depth
ARM_SGP_Burn; USARb; 35.5497; -98.0402; 10; 30; 5; 15
ARM_SGP_Control; USARc; 35.5465; -98.0401; 10; 30; 5; 15
ARM_SGP_Main; USARM; 36.6058; -97.4888; 5; 25; 5; 15
Atqasuk; USAAtq; 70.4696; -157.4089; -1; -1; 0; 5
Audubon_Grasslands; USAud; 31.5907; -110.5092; 10; 20; 2; 4
Austin_Cary; USSP1; 29.7381; -82.2188; -1; -1; 0; 5
Barrow; USBrw; 71.3225; -156.6259; -1; -1; 0; 5
Bartlett_Experimental_Forest; USBar; 44.0645; -71.2881; 10; -1; 5; -1
Blodgett_Forest; USBlo; 38.8953; -120.6328; 10; 20; 5; 10
Bondville; USBo1; 40.0062; -88.2904; 5; 20; 2; 4
.....
.....

```

```

Ameriflux observation directory:    ../AmeriFlux
Ameriflux station list file:       ../AmeriFlux/Ameriflux_stns.txt

```

7.5.19 ARM station observations

ARM observation directory: specifies the location of the ARM datasets **ARM site identifier name:** specifies the text identifier (e.g. sgp, twp, nsa, etc.)

ARM station list file: specifies the file that lists the location of the ARM stations. The format of the station list is as follows:

```
#nstns  
22  
#stnname; lat; lon  
E1; 38.202; -99.316  
E2; 38.306; -97.301  
E3; 38.201; -95.597  
E4; 37.953; -98.329  
E5; 38.114; -97.513  
E6; 37.842; -97.020  
E7; 37.383; -96.180  
E8; 37.333; -99.309  
E9; 37.133; -97.266  
.....  
.....
```

ARM observation directory: .../ARM_SGP
ARM site identifier name: sgp
ARM station list file: .../ARM_SGP/sgp_stns.txt

7.5.20 SMOSREX in-situ soil moisture observations

SMOSREX observation filename: specifies the name of the SMOSREX observation filename. Currently this plugin only handles a single observation location.

SMOSREX observation filename: ./SMOSREX/Toulouse_SMOSREX.dat

7.5.21 AGRMET data

AGRMET data directory: specifies the location of the AGRMET data.

AGRMET data directory: ./AGRMET_data/

7.5.22 GlobSnow data

GlobSnow data directory: specifies the location of the GlobSnow data.

GlobSnow data directory: ../GlobSnow

7.5.23 SNODEP data

SNODEP observation directory: specifies the location of the SNODEP observation data.

SNODEP observation directory: ./SNODEP

7.6 DA diagnostics analysis

This section of the config file specifies the specialized options to analyze the data assimilation diagnostics. These options are employed for runmode=2

Compute Innovation Distribution: Specifies if innovation distribution analysis (computing mean and variance) is to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

```
Compute Innovation Distribution:          0
Compute Analysis Gain:                  0
Number of state variables in the DA update: 0
```

7.7 Observation processing

This runmode is used to convert a given observational data into a "LIS style". Once the data is converted, intercomparisons with any observation-plugin in LVT can be made.

No specialized options are necessary, except that the 'LIS Output directory:' corresponds to the directory where the converted data will be written.

7.8 DA observation analysis

This runmode is used to conduct analysis of observations used in the DA assimilation instance. LIS DA subsystem generates processed (interpolated, QC'd) estimates of input observations. This runmode enables analysis of such data.

No specialized options are necessary, except specifying the 'LIS output attributes file:' option to correspond to the DA output. For example, if the DA instance generates estimates of a single variable (say SWE) then specify the LIS output attributes file such that (only) SWE is present in the (LIS) output file. In other words, column number 2 should indicate 1 for SWE variable and 0 for every other variable. If multiple observation types are present in the DA output, then column number 2 should be appropriately modified.

7.9 Optimization/Uncertainty Estimation output analysis

This section of the config file specifies the specialized options to analyze outputs from Optimization/Uncertainty Estimation algorithms.

The following options are for analyzing optimization/uncertainty estimation data output `OptUE algorithm used:` specifies the index of the optimization/uncertainty estimation algorithm used

Acceptable values are:

Value	Description
1	Levenberg- Marquardt
2	Genetic Algorithm
3	SCE-UA
4	MCSIM
5	MCMC
6	DEMC

OptUE algorithm used: 2

OptUE Decision Space Attributes File: lists the decision space attributes file used in the LIS optimization/uncertainty estimation integration.

OptUE Decision Space Attributes File: ./GArun/noah_sm_decspace.txt

Number of Iterations: Number of generations used in the optimization/uncertainty estimation algorithm.

OptUE Number of Iterations: 20

Compute OptUE time series: specifies if a time series of OptUE run output data is to be generated (0-no, 1-yes)

OptUE Compute time series: 1

OptUE Time series location file: specifies the file which lists the locations in the domain where the time series data are to be extracted. The format of the time series location file is as follows:

```
#Number of locations
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
2
#mask filename
none
#site name
```

Site1
244 236

OptUE Time series location file: ./STN_LOCATIONS.DAT

DRAFT

8 Model Output Specifications

This section defines the specification of the model output from LIS. This file is specified in a space delimited column format. Each row consists of the following entries:

Short Name ALMA compliant short name of the variable.

Use option determines whether to write the variable. Acceptable values are:

Value	Description
0	do not write the variable
1	write the variable

Units the desired unit of the output variable.

Time Average option determines how temporally process the variable. Acceptable values are:

Value	Description
0	Instantaneous output
1	Time averaged output
2	Instantaneous and Time averaged output
3	Accumulated output

Min/Max option determines whether to record minimum and maximum values for the variable. Acceptable values are:

Value	Description
0	Do no compute minimum and maximum values
1	Do compute minimum and maximum values

Number of vertical levels The number of vertical levels corresponding to the variable.

grib ID The grib ID to be used for the variable if output is written in grib1 format.

grib scale factor The grib scale factor to be used for the variable if output is written in grib1 format.

Use in LVT option determines whether to include the variable in the LVT analysis. Acceptable values are:

Value	Description
0	do not include the variable
1	include the variable

Note that this is a full list of output variables. Not all models support all these variables. You must check the source code to verify that the model you want to run supports the variables that you want to write.

```
#short_name select? units timeavg? vert.levels gribid longname
#Energy balance components
Swnet:      0 W/m2  1 0 0 1 111 10 0 # Net Shortwave Radiation (W/m2)
Lwnet:      0 W/m2  1 0 0 1 112 10 0 # Net Longwave Radiation (W/m2)
Qle:        0 W/m2  1 0 0 1 121 10 0 # Latent Heat Flux (W/m2)
Qh:         0 W/m2  1 0 0 1 122 10 0 # Sensible Heat Flux (W/m2)
Qg:         0 W/m2  1 0 0 1 155 10 0 # Ground Heat Flux (W/m2)
Qf:         0 W/m2  1 0 0 1 229 10 0 # Energy of fusion (W/m2)
Qv:         0 W/m2  1 0 0 1 134 10 0 # Energy of sublimation (W/m2)
Qa:         0 W/m2  1 0 0 1 136 10 0 # Advective Energy (W/m2)
Qtau:       0 W/m2  1 0 0 1 135 10 0 # Momentum flux (N/m2)
DelSurfHeat: 0 W/m2  1 0 0 1 137 10 0 # Change in surface heat storage (J/m2)
DelColdCont: 0 W/m2  1 0 0 1 138 10 0 # Change in snow cold content (J/m2)
BR:          0 -     1 0 0 1 138 10 0 # Change in snow cold content (J/m2)
EF:          0 -     1 0 0 1 138 10 0 # Change in snow cold content (J/m2)

#Water balance components
Snowf:      0 kg/m2s 1 0 0 1 161 10000 0 # Snowfall rate (kg/m2s)
Rainf:      0 kg/m2s 1 0 0 1 162 10000 0 # Rainfall rate (kg/m2s)
RainfConv:   0 kg/m2s 1 0 0 0 163 10000 0 # Convective Rainfall rate (kg/m2s)
TotalPrecip: 0 kg/m2s 1 0 0 0 164 10000 0 # Total Precipitation rate (kg/m2s)
Evap:        1 kg/m2s 1 0 0 1 57 10000 0 # Total Evapotranspiration (kg/m2s)
Qs:          1 kg/m2  1 0 0 1 235 10000 0 # Surface runoff (kg/m2s)
Qrec:        0 kg/m2  1 0 0 0 143 10000 0 # Recharge (kg/m2s)
Qsb:         1 kg/m2  1 0 0 1 254 10000 0 # Subsurface runoff (kg/m2s)
Qsm:         1 kg/m2  0 0 0 1 99 10000 0 # Snowmelt (kg/m2s)
Qfz:         0 kg/m2s 1 0 0 0 146 10000 0 # Refreezing of water in the snowpack (kg/m2s)
Qst:         0 kg/m2s 1 0 0 0 147 10000 0 # Snow throughfall (kg/m2s)
DelSoilMoist: 0 kg/m2  1 0 0 0 148 10000 0 # Change in soil moisture (kg/m2)
DelSWE:       0 kg/m2  1 0 0 0 149 1000 0 # Change in snow water equivalent (kg/m2)
DelSurfStor:  0 kg/m2  1 0 0 0 150 1000 0 # Change in surface water storage (kg/m2)
DelIntercept: 0 kg/m2  1 0 0 0 151 1000 0 # Change in interception storage (kg/m2)
RHMin:       0 -     0 0 0 0 51 10 0 # Minimum 2 meter relative humidity (-)

#Surface State Variables
SnowT:       0 K      1 0 0 1 152 10 0 # Snow surface temperature (K)
VegT:        0 K      1 0 0 0 153 10 0 # Vegetation canopy temperature (K)
```

```

BareSoilT:    0   K      1 0 0 0 154 10 0 # Temperature of bare soil (K)
AvgSurfT:    0   K      1 0 0 1 148 10 0 # Average surface temperature (K)
RadT:        0   K      1 0 0 0 156 10 0 # Surface Radiative Temperature (K)
Albedo:       0   -      1 0 0 1 84 100 0 # Surface Albedo (-)
SWE:          1   m      0 0 0 1 65 1000 0 # Snow Water Equivalent (kg/m2)
SnowDepth:    1   m      1 0 0 1 66 1000 1 # Snow Depth (m)
Snowcover:    1   -      1 0 0 1 66 100 0 # Snow Depth (m)
SWEVeg:       0   kg/m2  1 0 0 0 159 1000 0 # SWE intercepted by vegetation (kg/m2)
SurfStor:     0   kg/m2  1 0 0 0 160 1000 0 # Surface water storage (kg/m2)
SLiqFrac:     0   -      0 0 0 0 65 1000 0 # fraction of SWE in the liquid phase
RootTemp:     0   K      1 0 0 1 65 1000 0 # fraction of SWE in the liquid phase

#Subsurface State Variables
SoilMoist:   0   m3/m3  1 0 0 4 86 1000 0 # Average layer soil moisture (kg/m2)
SoilTemp:    0   K      1 0 0 4 85 1000 0 # Average layer soil temperature (K)
SmLiqFrac:   0   kg/m2  1 1 0 0 85 100 0 # Average layer fraction of liquid moisture (-)
SmFrozFrac:  0   kg/m2  1 1 0 0 85 100 0 # Average layer fraction of frozen moisture (-)
SoilWet:     0   kg/m2  1 1 0 0 85 100 0 # Total soil wetness (-)
RelSMC:      0   m3/m3  0 0 0 0 86 1000 0 # Relative soil moistutre

#Evaporation components
PotEvap:     0   kg/m2s  1 1 0 0 166 1 0 # Potential Evapotranspiration (kg/m2s)
ECanop:       0   kg/m2s  1 1 0 0 200 1 0 # Interception evaporation (kg/m2s)
TVeg:         0   kg/m2s  1 1 0 0 210 1 0 # Vegetation transpiration (kg/m2s)
ESoil:        0   kg/m2s  1 1 0 0 199 1 0 # Bare soil evaporation (kg/m2s)
EWater:       0   kg/m2s  1 1 0 0 170 1 0 # Open water evaporation (kg/m2s)
RootMoist:   0   m3/m3  1 0 0 1 171 1 0 # Root zone soil moisture (kg/m2)
CanopInt:    0   kg/m2  1 0 0 1 223 1000 0 # Total canopy water storage (kg/m2)
EvapSnow:    0   kg/m2s  1 1 0 0 173 1000 0 # Snow evaporation (kg/m2s)
SubSnow:     0   kg/m2s  1 1 0 0 198 1000 0 # Snow sublimation (kg/m2s)
SubSurf:    0   kg/m2s  1 1 0 0 175 1000 0 # Sublimation of the snow free area (kg/m2s)
ACond:       0   m/s    1 1 0 0 179 10000 0 # Aerodynamic conductance
CCond:       0   m/s    1 0 0 0 179 1000000 0 # Canopy conductance

#Forcings
Wind_f:      0   m/s    1 0 0 1 177 10 0 # Near Surface Wind (m/s)
Rainf_f:     1   kg/m2s  1 0 0 1 162 1000 0 # Average rainfall rate
Snowf_f:     0   kg/m2s  0 1 0 0 161 1000 0 # Average snowfall rate
Tair_f:      0   K      1 0 0 1 11 10 0 # Near surface air temperature
Qair_f:      0   kg/kg   1 0 0 1 51 1000 0 # Near surface specific humidity
Psurf_f:     0   Pa     1 0 0 1 1 10 0 # Surface pressure
SWdown_f:    0   W/m2   1 0 0 1 204 10 0 # Surface incident shortwave radiation
Lwdown_f:    0   W/m2   1 0 0 1 205 10 0 # Surface incident longwave radiation

#Parameters
Landmask:    1   -  0 1 0 0 81 1 0 # Land Mask (0 - Water, 1- Land)

```

Landcover: 1 - 0 1 0 0 186 1 0 # Land cover
Soiltype: 0 - 0 1 0 0 187 1 0 # soil type
SandFrac: 1 - 0 1 0 0 999 1 0 # sand fraction
ClayFrac: 1 - 0 1 0 0 999 1 0 # clay fraction
SiltFrac: 1 - 0 1 0 0 999 1 0 # silt fraction
Porosity: 0 - 3 1 0 0 999 1 0 # porosity
Soilcolor: 0 - 0 1 0 0 188 1 0 # soil color
Elevation: 1 m 0 1 0 0 189 10 0 # elevation
Slope: 0 - 0 1 0 0 999 10 0 # slope
LAI: 0 - 0 1 0 0 190 100 0 # LAI
SAI: 0 - 0 1 0 0 191 100 0 # SAI
Snfralbedo: 0 - 0 1 0 0 192 100 0 #
Mxsnalbedo: 0 - 0 1 0 0 192 100 0 #
Greenness: 1 - 0 1 0 0 87 100 0 #
Tempbot: 0 - 0 1 0 0 194 10 0 #

A LVT output file structure

The LVT output files contain the results from different analyses that are specified through the options in `lvt.config`. This section describes the structure of the analysis files.

As mentioned earlier, the basic structure of the output file is determined by the `LVT Output methodology` option (tiled or gridded). In each file, the order of variables follow their selection in the `MODEL_OUTPUT_LIS_LVT.TBL` file. For example, if the `MODEL_OUTPUT_LIS_LVT.TBL` is defined as follows (i.e., three variables `Qle`, `Qh` and `Qg` are selected in the LVT comparisons):

```
Swnet:      1  W/m2  1  0 0 1 111 10 0 # Net Shortwave Radiation (W/m2)
Lwnet:      1  W/m2  1  0 0 1 112 10 0 # Net Longwave Radiation (W/m2)
Qle:        1  W/m2  1  0 0 1 121 10 1 # Latent Heat Flux (W/m2)
Qh:         1  W/m2  1  0 0 1 122 10 1 # Sensible Heat Flux (W/m2)
Qg:         1  W/m2  1  0 0 1 155 10 1 # Ground Heat Flux (W/m2)
.....
.....
.....
```

Then the LVT output files will have three variables, in the same order (i.e., `Qle`, `Qh` and `Qg`).

The files corresponding to the analysis computations (Mean, RMSE, Bias, etc.) have the following ordering: The variable name followed by the total number of grid points included in the comparisons. For the above example, the ordering of variables in the analysis files will be as follows:

```
Qle
nQle
Qh
nQh
Qg
nQG
```

B Cylindrical Lat/Lon Domain Example

This section describes how to compute the values for the run domain and param domain sections on a cylindrical lat/lon projection.

First, we shall generate the values for the parameter data domain. LIS' parameter data is defined on a Latitude/Longitude grid, from -180 to 180 degrees longitude and from -60 to 90 degrees latitude.

For this example, consider running at $1/4$ deg resolution. The coordinates of the south-west and the north-east points are specified at the grid-cells' centers. Here the south-west grid-cell is given by the box $(-180, -60), (-179.750, -59.750)$. The center of this box is $(-179.875, -59.875)$.¹

```
param domain lower left lat: -59.875  
param domain lower left lon: -179.875
```

The north-east grid-cell is given by the box $(179.750, 89.750), (180, 90)$. Its center is $(179.875, 89.875)$.

```
param domain upper right lat: 89.875  
param domain upper right lon: 179.875
```

Setting the resolution (0.25 deg) gives

```
param domain resolution dx: 0.25  
param domain resolution dy: 0.25
```

And this completely defines the parameter data domain.

Next, we shall generate the values for the running domain.

If you wish to run over the whole domain defined by the parameter data domain then you simply set the values defined in the parameter domain section in the run domain section. This gives:

```
run domain lower left lat: -59.875  
run domain lower left lon: -179.875  
run domain upper right lat: 89.875  
run domain upper right lon: 179.875  
run domain resolution dx: 0.25  
run domain resolution dy: 0.25
```

Now say you wish to run only over the region given by $(-97.6, 27.9), (-92.9, 31.9)$. Since the running domain is a sub-set of the parameter domain, it is also a Latitude/Longitude domain at $1/4$ deg. resolution. Thus,

```
run domain resolution dx: 0.25  
run domain resolution dy: 0.25
```

Now, since the running domain must fit onto the parameter domain, the desired running region must be expanded from $(-97.6, 27.9), (-92.9, 31.9)$ to $(-97.75, 27.75), (-92.75, 32.0)$. The south-west grid-cell for the running domain is the box $(-97.75, 27.75), (-97.5, 28.0)$. Its center is $(-97.625, 27.875)$; giving

¹Note, these coordinates are ordered (longitude, latitude).

```
run domain lower left lat: 27.875  
run domain lower left lon: -97.625
```

The north-east grid-cell for the running domain is the box $(-93, 31.75), (-92.75, 32.0)$. Its center is $(-92.875, 31.875)$; giving

```
run domain upper right lat: 31.875  
run domain upper right lon: -92.875
```

This completely defines the running domain.

Note, the LIS project has defined 5 km resolution to be 0.05 deg. and 1 km resolution to be 0.01 deg. If you wish to run at 5 km or 1 km resolution, redo the above example to compute the appropriate grid-cell values.

See Figure 1 for an illustration of adjusting the running grid. See Figures 2 and 3 for an illustration of the south-west and north-east grid-cells.

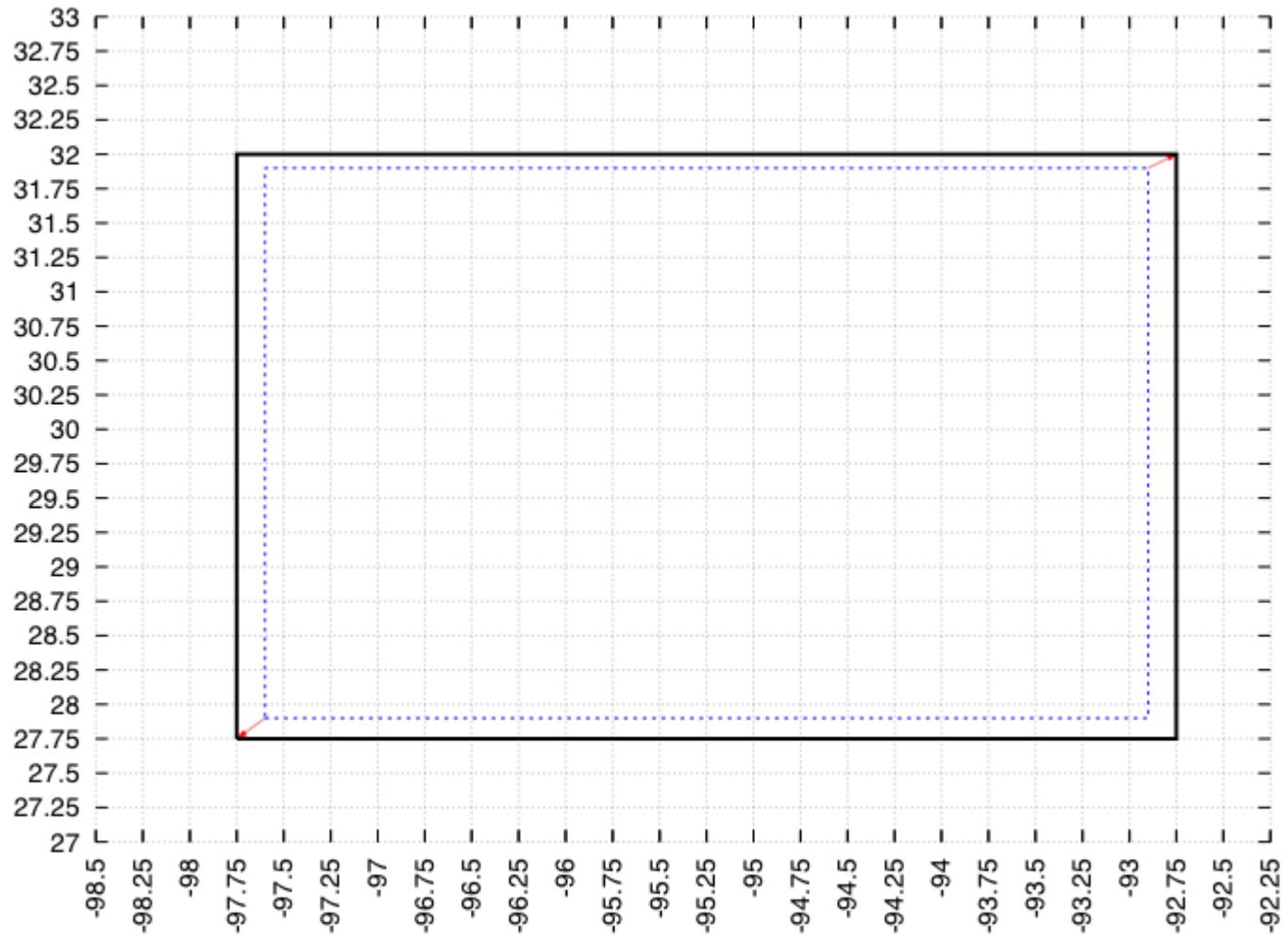


Figure 1: Illustration showing how to fit the desired running grid onto the actual grid

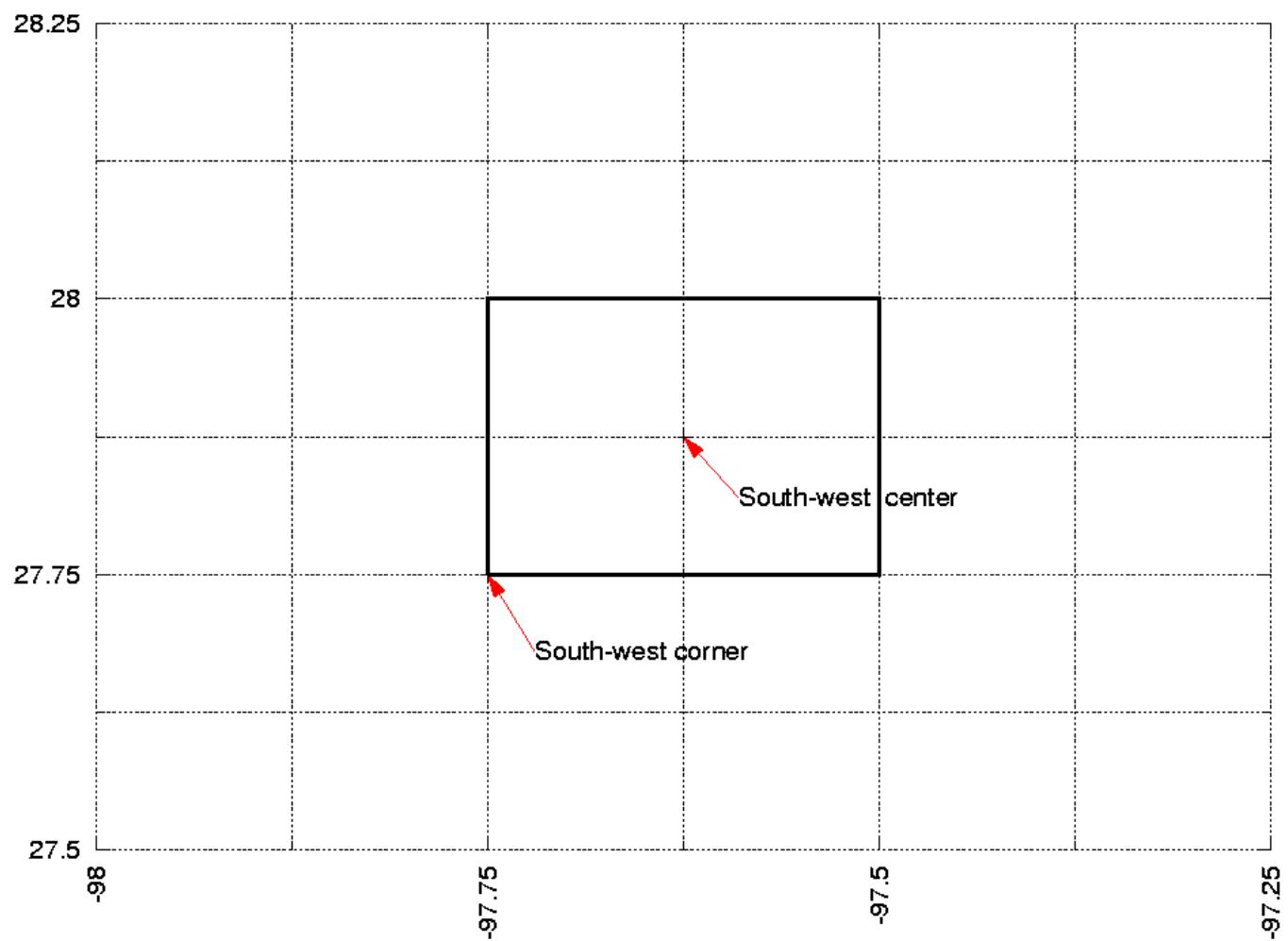


Figure 2: Illustration showing the south-west grid-cell corresponding to the example in Section B

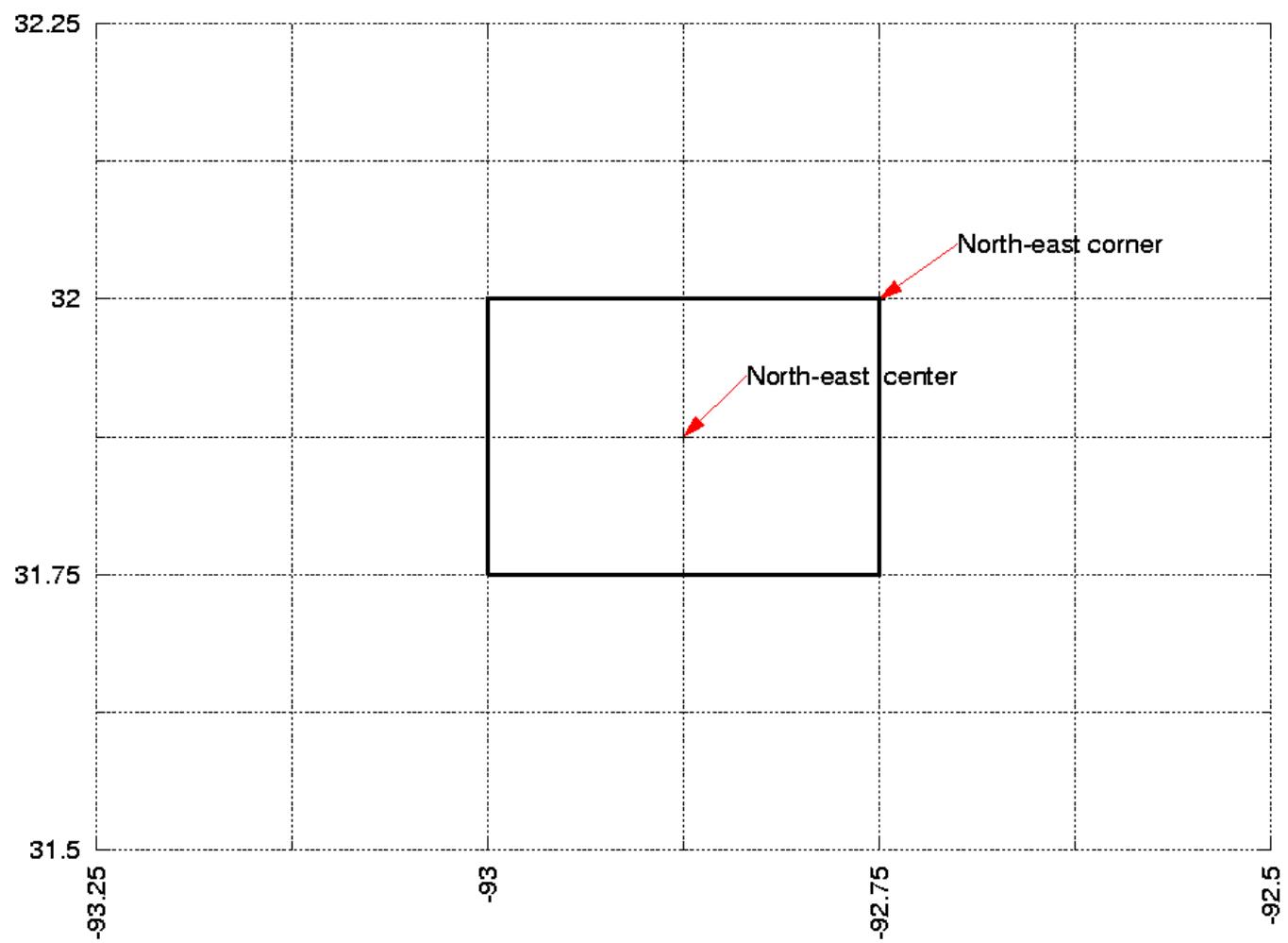


Figure 3: Illustration showing the north-east grid-cell corresponding to the example in Section B

C Polar Stereographic Domain Example

This section describes how to compute the values for the run domain and param domain sections on a polar stereographic projection.

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D Gaussian Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Gaussian projection.

First, we shall generate the values for the parameter data domain. LIS' Gaussian parameter data is defined from -180 to 180 degrees longitude and from -90 to 90 degrees latitude. Note that the first longitude point is at 0 .

The parameter domain must be specified as follows:

```
param domain first grid point lat:      -89.27665
param domain first grid point lon:      0.0
param domain last grid point lat:       89.27665
param domain last grid point lon:      -0.9375
param domain resolution dlon:          0.9375
param domain number of lat circles:    95
```

Next, we shall generate the values for the running domain.

If you wish to run over the whole domain defined by the parameter data domain then you simply set the values defined in the parameter domain section in the run domain section. This gives:

```
run domain first grid point lat:      -89.27665
run domain first grid point lon:      0.0
run domain last grid point lat:       89.27665
run domain last grid point lon:      -0.9375
run domain resolution dlon:          0.9375
run domain number of lat circles:    95
```

If you wish to run over a sub-domain, then you must choose longitude and latitude values that correspond to the T126 Gaussian projection. Tables of acceptable longitude and latitude values are found below.

Now say you wish to run only over the region given by $(-97.6, 27.9), (-92.9, 31.9)$. Since the running domain must fit on the T126 Gaussian grid, the running domain must be expanded to $(-98.4375, 27.87391), (-91.875, 32.59830)$. Thus the running domain specification is:

```
run domain first grid point lat:      27.87391
run domain first grid point lon:      -98.4375
run domain last grid point lat:       32.59830
run domain last grid point lon:      -91.875
run domain resolution dlon:          0.9375
run domain number of lat circles:    95
```

Table 1: Acceptable longitude values

0.000000	0.937500	1.875000	2.812500	3.750000
4.687500	5.625000	6.562500	7.500000	8.437500
9.375000	10.312500	11.250000	12.187500	13.125000
14.062500	15.000000	15.937500	16.875000	17.812500
18.750000	19.687500	20.625000	21.562500	22.500000
23.437500	24.375000	25.312500	26.250000	27.187500
28.125000	29.062500	30.000000	30.937500	31.875000
32.812500	33.750000	34.687500	35.625000	36.562500
37.500000	38.437500	39.375000	40.312500	41.250000
42.187500	43.125000	44.062500	45.000000	45.937500
46.875000	47.812500	48.750000	49.687500	50.625000
51.562500	52.500000	53.437500	54.375000	55.312500
56.250000	57.187500	58.125000	59.062500	60.000000
60.937500	61.875000	62.812500	63.750000	64.687500
65.625000	66.562500	67.500000	68.437500	69.375000
70.312500	71.250000	72.187500	73.125000	74.062500
75.000000	75.937500	76.875000	77.812500	78.750000
79.687500	80.625000	81.562500	82.500000	83.437500
84.375000	85.312500	86.250000	87.187500	88.125000
89.062500	90.000000	90.937500	91.875000	92.812500
93.750000	94.687500	95.625000	96.562500	97.500000
98.437500	99.375000	100.312500	101.250000	102.187500
103.125000	104.062500	105.000000	105.937500	106.875000
107.812500	108.750000	109.687500	110.625000	111.562500
112.500000	113.437500	114.375000	115.312500	116.250000
117.187500	118.125000	119.062500	120.000000	120.937500
121.875000	122.812500	123.750000	124.687500	125.625000
126.562500	127.500000	128.437500	129.375000	130.312500
131.250000	132.187500	133.125000	134.062500	135.000000
135.937500	136.875000	137.812500	138.750000	139.687500
140.625000	141.562500	142.500000	143.437500	144.375000
145.312500	146.250000	147.187500	148.125000	149.062500
150.000000	150.937500	151.875000	152.812500	153.750000
154.687500	155.625000	156.562500	157.500000	158.437500
159.375000	160.312500	161.250000	162.187500	163.125000
164.062500	165.000000	165.937500	166.875000	167.812500
168.750000	169.687500	170.625000	171.562500	172.500000
173.437500	174.375000	175.312500	176.250000	177.187500
178.125000	179.062500	180.000000	-179.062500	-178.125000

-177.187500	-176.250000	-175.312500	-174.375000	-173.437500
-172.500000	-171.562500	-170.625000	-169.687500	-168.750000
-167.812500	-166.875000	-165.937500	-165.000000	-164.062500
-163.125000	-162.187500	-161.250000	-160.312500	-159.375000
-158.437500	-157.500000	-156.562500	-155.625000	-154.687500
-153.750000	-152.812500	-151.875000	-150.937500	-150.000000
-149.062500	-148.125000	-147.187500	-146.250000	-145.312500
-144.375000	-143.437500	-142.500000	-141.562500	-140.625000
-139.687500	-138.750000	-137.812500	-136.875000	-135.937500
-135.000000	-134.062500	-133.125000	-132.187500	-131.250000
-130.312500	-129.375000	-128.437500	-127.500000	-126.562500
-125.625000	-124.687500	-123.750000	-122.812500	-121.875000
-120.937500	-120.000000	-119.062500	-118.125000	-117.187500
-116.250000	-115.312500	-114.375000	-113.437500	-112.500000
-111.562500	-110.625000	-109.687500	-108.750000	-107.812500
-106.875000	-105.937500	-105.000000	-104.062500	-103.125000
-102.187500	-101.250000	-100.312500	-99.375000	-98.437500
-97.500000	-96.562500	-95.625000	-94.687500	-93.750000
-92.812500	-91.875000	-90.937500	-90.000000	-89.062500
-88.125000	-87.187500	-86.250000	-85.312500	-84.375000
-83.437500	-82.500000	-81.562500	-80.625000	-79.687500
-78.750000	-77.812500	-76.875000	-75.937500	-75.000000
-74.062500	-73.125000	-72.187500	-71.250000	-70.312500
-69.375000	-68.437500	-67.500000	-66.562500	-65.625000
-64.687500	-63.750000	-62.812500	-61.875000	-60.937500
-60.000000	-59.062500	-58.125000	-57.187500	-56.250000
-55.312500	-54.375000	-53.437500	-52.500000	-51.562500
-50.625000	-49.687500	-48.750000	-47.812500	-46.875000
-45.937500	-45.000000	-44.062500	-43.125000	-42.187500
-41.250000	-40.312500	-39.375000	-38.437500	-37.500000
-36.562500	-35.625000	-34.687500	-33.750000	-32.812500
-31.875000	-30.937500	-30.000000	-29.062500	-28.125000
-27.187500	-26.250000	-25.312500	-24.375000	-23.437500
-22.500000	-21.562500	-20.625000	-19.687500	-18.750000
-17.812500	-16.875000	-15.937500	-15.000000	-14.062500
-13.125000	-12.187500	-11.250000	-10.312500	-9.375000
-8.437500	-7.500000	-6.562500	-5.625000	-4.687500
-3.750000	-2.812500	-1.875000	-0.937500	

Table 2: Acceptable latitude values

-89.27665	-88.33975	-87.39729	-86.45353	-85.50930
-84.56487	-83.62028	-82.67562	-81.73093	-80.78618
-79.84142	-78.89662	-77.95183	-77.00701	-76.06219
-75.11736	-74.17252	-73.22769	-72.28285	-71.33799
-70.39314	-69.44830	-68.50343	-67.55857	-66.61371
-65.66885	-64.72399	-63.77912	-62.83426	-61.88939
-60.94452	-59.99965	-59.05478	-58.10991	-57.16505
-56.22018	-55.27531	-54.33043	-53.38556	-52.44069
-51.49581	-50.55094	-49.60606	-48.66119	-47.71632
-46.77144	-45.82657	-44.88169	-43.93681	-42.99194
-42.04707	-41.10219	-40.15731	-39.21244	-38.26756
-37.32268	-36.37781	-35.43293	-34.48805	-33.54317
-32.59830	-31.65342	-30.70854	-29.76366	-28.81879
-27.87391	-26.92903	-25.98415	-25.03928	-24.09440
-23.14952	-22.20464	-21.25977	-20.31489	-19.37001
-18.42513	-17.48025	-16.53537	-15.59050	-14.64562
-13.70074	-12.75586	-11.81098	-10.86610	-9.921225
-8.976346	-8.031467	-7.086589	-6.141711	-5.196832
-4.251954	-3.307075	-2.362196	-1.417318	-0.4724393
0.4724393	1.417318	2.362196	3.307075	4.251954
5.196832	6.141711	7.086589	8.031467	8.976346
9.921225	10.86610	11.81098	12.75586	13.70074
14.64562	15.59050	16.53537	17.48025	18.42513
19.37001	20.31489	21.25977	22.20464	23.14952
24.09440	25.03928	25.98415	26.92903	27.87391
28.81879	29.76366	30.70854	31.65342	32.59830
33.54317	34.48805	35.43293	36.37781	37.32268
38.26756	39.21244	40.15731	41.10219	42.04707
42.99194	43.93681	44.88169	45.82657	46.77144
47.71632	48.66119	49.60606	50.55094	51.49581
52.44069	53.38556	54.33043	55.27531	56.22018
57.16505	58.10991	59.05478	59.99965	60.94452
61.88939	62.83426	63.77912	64.72399	65.66885
66.61371	67.55857	68.50343	69.44830	70.39314
71.33799	72.28285	73.22769	74.17252	75.11736
76.06219	77.00701	77.95183	78.89662	79.84142
80.78618	81.73093	82.67562	83.62028	84.56487
85.50930	86.45353	87.39729	88.33975	89.27665

E Lambert Conformal Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Lambert conformal projection.

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F Mercator Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Mercator projection.

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G UTM Domain Example

This section describes how to compute the values for the run domain and param domain sections on a UTM projection.

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H configure.lvt

This is a sample *configure.lvt* file used for compiling LVT on the NCCS discover machine (Linux, 64bit with intel compiler)

```
FC          =      mpif90
FC77        =      mpif90
LD          =      mpif90
CC          =      mpicc
AR          =      ar ru
INC_NETCDF  = /home/user/lib/netcdf-3.6.3/include/
LIB_NETCDF  = /home/user/lib/netcdf-3.6.3/lib/
LIB_ESMF    = /home/user/esmf/lib/lib0/Linux.intel.64.mpi.default/
MOD_ESMF   = /home/user/mod/mod0/Linux.intel.64.mpi.default/
CFLAGS      = -c -DIFC
FFLAGS77    = -c -O0 -nomixed_str_len_arg -names lowercase \
              -convert big_endian -assume byterecl -DHIDE_SHR_MSG \
              -DNO_SHR_VMATH -DIFC -I$(MOD_ESMF) -DSPMD -DUSE_INCLUDE_MPI

FFLAGS       = -c -g -u -traceback -fpe0 -nomixed_str_len_arg \
              -names lowercase -convert big_endian -assume byterecl \
              -DHIDE_SHR_MSG -DNO_SHR_VMATH -DIFC -I$(MOD_ESMF) \
              -I$(INC_NETCDF) -DUSE_INCLUDE_MPI
LDFLAGS     = ./lib/w3lib/libw3.a ./lib/read_grib/readgrib.a \
              ./lib/grib/griblib.a -lmpi -L$(LIB_NETCDF) -lnetcdf \
              -L$(LIB_ESMF) -lesmf \
              -lstdc++ -limf -lm -lgcc -lgcc_s -lrt
```

References

- [1] W. Sawyer and A. da Silva. Protex: A sample fortran 90 source code documentation system. Technical report, NASA GMAO, 1997. DAO Office Note 97-11.

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